E298A/EECS 290B Problem Set 3 (due 4/14/05)

1. A blanker in an electron beam lithography tool consists of a set of parallel plates with area A, length L, and gap D. Ignoring the fringing fields, what is the capacitance of the structure? With a voltage difference, V, on the plates, what is the E field inside the structure? What is the potential function, V(x,y,z)? If an electron has a velocity V_z in the Z direction as it enters the structure, what is the force that the electron experiences inside the structure? Integrate the force equation to get the velocity and position of the electron as it exits the structure. The Hamiltonian is used to derive the Liouville equation and plays an important role in quantum mechanics. It is given by:

$\mathbf{H} = (p^2)/(2m) + V(qx,qy,qz)$.

Show by direct substitution of the above solution, that the equations of motion given by the Hamiltonian are satisfied,

$q' = \partial\mathbf{H}/\partial p$

$p' = -\partial\mathbf{H}/\partial q$

where q represents the position coordinates (i.e. x,y,z) and p the momentum coordinates.

2. Because of the interaction between the beam and the substrate, electrons are scattered backward by the substrate and expose the resist coating. We would like to find out the radius to which the electrons are scattered by a plain Si substrate and the amount of backscatter.

a. Here is the dot measurement we collected for KRS-XE on plain Si:

Dose (uC/cm^2)	Radius (nm)
2.50E+08	43400
1.93E+08	41100
1.49E+08	38550
1.15E+08	35450
8.85E+07	32050
6.82E+07	27400
5.26E+07	20750
4.06E+07	9800
3.13E+07	5950
2.42E+07	4675
1.86E+07	3280
1.44E+07	2890
1.11E+07	2665
8.55E+06	1855
6.59E+06	1545
5.09E+06	1375
3.92E+06	1250
3.03E+06	1190
2.33E+06	1050
1.80E+06	950
1.39E+06	870
1.07E+06	795
8.26E+05	720
6.37E+05	675
3.79E+05	545

2.26E+05	468
1.34E+05	391
1.03E+05	352.5
6.16E+04	307.5
3.66E+04	259
2.18E+04	221
1.30E+04	181

A double Gaussian model for point exposure distribution proposed by T.H. P. Chang [J. Vac. Sci. Technol. **12**, 1271 (1975)], has the following form:

$$f(r) = \frac{1}{\pi(1+\eta)}[\frac{1}{\alpha^2}e^{-(\frac{r}{a})^2} + \frac{\eta}{\beta^2}e^{-(\frac{r}{\beta})^2}]$$

The first and second terms in the bracket express the forward scattering and backscattering. In our experiment, we only focus on the backscatter part. Using the data above, plot dose vs. radius and calculate the beta value. Express the answer in microns.

b. You can also find the amount of backscatter from the above experiment. Explain how. An easier way to obtain this quantity is by measuring the shift in dose when exposing small features. Calculate the ratio of the backscatter to the forward scatter on the AZPN114 on Si from the measurements below.

5 µm Square Pad		**76 µm x 160 µm Wedge**	
Dose (µC/cm^2)	Height (Å)	Dose(µC/cm^2)	Height (Å)
100.6591	2508	100.6591	2497
86.77509	2434	86.77509	2479
74.80611	2424	74.80611	2500
64.48803	2437	64.48803	2447
55.59313	2433	55.59313	2508
47.92511	2409	47.92511	2449
41.31475	2252	41.31475	2465
35.61616	2184	35.61616	2387
30.70359	1854	30.70359	2358
26.46861	1584	26.46861	2311
22.81777	443	22.81777	2219
		19.67049	2016
		16.95732	1737
		14.61838	1238
		12.60205	533

Plot the sensitivity curves for the two features and obtain the ratio value. What are the possible errors in the measurement? How would you evaluate each error?

3. Plot the aerial image (i.e. the ideal energy distribution before the beam is incident on the resist) for a 20 nm isolated line and for an array of 5 20 nm line/space pairs by convolving a Gaussian with the appropriate top-hat or square wave functions for Gaussians with σ values of 1, 5, and 10 nm.

4. Use the dissolution rate contrast, $\gamma = d\ln(r)/d\ln(D)$ to plot contrast curves (normalized film thickness vs ln(D), for a positive resist with γ values of 1, 10 and 100. You may assume that the development rate, r_0, that results from a dose of D_0 is sufficient to just clear the resist after the allotted development time, so that $r(D) = (D/D_0)^{\gamma}$.

5. Plot the developed resist profiles for the energy deposition distributions calculated in problem 4 for the σ value of 5 nm and for γ values of 1, 10 and 100.